

The early X-ray afterglows of optically bright and dark Gamma-Ray Bursts

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Abstract A systematical study on the early X-ray afterglows of both optically bright and dark gamma-ray bursts (B-GRBs and D-GRBs) observed by Swift has been presented. Our sample includes 25 GRBs. Among them 13 are B-GRBs and 12 are D-GRBs. Our results show that the distributions of the X-ray afterglow fluxes (F_X), the gamma-ray fluxes (S_γ), and the ratio ($R_{\gamma,X}$) for both the D-GRBs and B-GRBs are similar. The differences of these distributions for the two kinds of GRBs should be statistical fluctuation. These results indicate that the progenitors of the two kinds of GRBs are the same population. Their total energy explosions are comparable. The suppression of the optical emissions from D-GRBs should results from circumburst but not their central engine.

Key words: gamma rays: bursts

1 INTRODUCTION

Over the 8 years since the afterglow was discovered, more than one hundred of bursts were well-localized and their counterparts in the X-ray, optical/IR, and radio bands were detected. About ninety percent of these well-localized bursts are X-ray afterglow detected, but about half of them have not optical transient (OT) detection, which are the so called optically dark GRBs (Groot et al. 1998; Fynbo et al. 2001; Reichart & Yost 2001). Before Swift era being due to the lack of early afterglow observations, it is thought that dark bursts might be a bias of late and shallow observations. However, very tight limits at very early phases made by Swift UV-optical telescope (UVOT) have shown that about 50% of swift GRBs are indeed phenomenally dark (Roming et al. 2005). The

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nature of the dark GRBs becomes a great issue. Several arguments have been proposed for explanation of the nature of dark bursts. Extinction by dust and gas of host galaxy (e.g., Taylor et al. 1998; Djorgovski et al. 2001; Piro et al. 2002) and/or circumburst absorption (Lazzati, Covino, & Ghisellini 2002; Fynbo et al. 2002) are intuitionistic explanations. However, the faintness and relatively rapid decay of the afterglow of bright GRB 020124, combined with the low inferred extinction, indicate that some dark bursts are intrinsically dim and not dust obscured (Berger et al. 2002). The Ly- α blanketing and absorption effect due to high redshift is also proposed (Fynbo et al. 2002; Groot et al. 1998). However, the redshifts of two typical dark bursts, GRB970828 and GRB000210, are normal as bright GRBs. Recently, Roming et al. (2005) argued that dark GRBs may be intrinsically faint and/or high efficiency gamma-ray emissions, which should result in their cooling frequency closed to the X-ray band (Pedersen et al. 2005) and faint at optical wavelengths (e.g. Lazzati, Covino, & Ghisellini 2002; Fynbo et al. 2002).

X-ray afterglow is a main probe to detect the difference of bright and dark GRBs. De Pasquale et al. (2003) systematically compared the X-ray fluxes by extrapolating the X-ray flux to 10 hours after GRB trigger and found that dark GRBs tend to have a lower X-ray fluxes. Jakobsson et al. (2004) used a jointed optical-to-X-ray spectral index to discriminate the dark and bright GRBs by the X-ray and optical afterglows at 11 hours since GRB trigger. Rol et al. (2005) try to quantify the degree of the optical darkness by comparing optical upper limits and the inferred optical fluxes from X-ray fluxes based on standard afterglow model. However, two significant biases are involved in the late X-ray afterglow data used by previous authors. The first one is sample biased. Being due to the lack of early and deep optical observation, some previous dark GRBs might be bright GRBs. The optical afterglow observations of previous GRBs were made at significantly different epoch. This also results in an inhomogenous effect for the sample selection. Secondly, XRT observations have revealed that the early X-ray afterglows of GRBs are enormously different from the late ones. In this work we systematically analyze the early X-ray afterglows observed by the Swift/XRT for bright and dark GRBs. We collect the Swift GRB data up to June, 2005. There are 25 bursts are included. We present our sample in section 2. The results are presented in section 3, 4 and section 5. Conclusion and discussion are presented in section 6.

2 SAMPLES

For seeking of homogeneity and reliability, we include only Swift GRBs into our sample. Twenty-five GRBs are included. We identify those GRBs without OT detection by Swift/UVOT and(or) ground-based telescopes as dark GRBs. In our sample 12 bursts are dark GRBs.

The X-ray afterglow of the bursts in our sample are observed by Swift/XRT from $\sim 10^2$ s up to 10^5 s since GRB trigger. We measure the X-ray afterglows at a given time for our purpose. This given time should be early enough and the X-ray fluxes at this time should be reliably measured from the XRT light curves of most bursts. We take this time as 1 hour after GRB trigger. Our considerations are as follows. First, most of the XRT light curves have a bright and steep tail in the early phase lasting from $\sim 10^2$ s up to $\sim 10^3$ s. These tails are believed to be from prompt emissions. To reduce the contamination from the tail emissions, we should select a time that it is later than 10^3 seconds. Second, more than half of the XRT light curves have a gap around 1500-3000 seconds lacking of observations. We should also skip this period. We notice that around 1 hour since GRB trigger most of XRT light curves begin to evolve as power law with a normal index (~ -1). At this time the fluxes are also not affect by the jet effect¹. We thus study the X-ray flux at 1 hour since GRBs trigger.

Their X-ray afterglow fluxes (F_X) at 1 hour after GRB trigger are read off or extrapolated/interpolated from their X-ray light curves observed by Swift X-ray telescope (XRT). Their gamma-ray fluences S_γ and the duration (T_{90}) in 15-350 keV are also collected from literature. They are listed in Table 1 with the followings headings: GRB, gamma-ray fluence (S_γ) in 15-350 keV band (in unit of 10^{-6} ergs cm $^{-2}$), GRB duration (T_{90}) in 15-350 keV, X-ray afterglow flux (F_X) in 0.3-10 keV band at 1 hour since GRB trigger, and references.

3 EARLY X-RAY FLUX AS A FUNCTION OF GAMMA-RAY FLUENCES

With the data shown in Table 1 we show the two-dimensional distributions of the gamma-ray fluences and the X-ray fluxes in Figure 1. It shows that the two quantities are correlated for both the B-GRBs and the D-GRBs (panel a), with Spearman correlation coefficient $r = 0.79 \pm 0.40$ (the chance probability $p < 0.0001$) for B-GRBs and $r = 0.60 \pm 0.58$ ($p = 0.01$) for the D-GRBs. The best fitting results are also shown in the panel (a) of Figure 1. They show that the D-GRBs tend to have a larger ratio of S_γ/F_X than the B-GRBs. The dispersion of the correlation for the D-GRBs is significantly larger than that for the B-GRBs.

From Figure 1 one can observe that both S_γ and F_X expand almost the same ranges for the D-GRBs and B-GRBs. While the S_γ of the D-GRBs tends to be slightly larger than that of the B-GRBs, the F_X of the D-GRBs tends to be slightly smaller than that of the B-GRBs.

¹ The jet break is usually greater than half a day

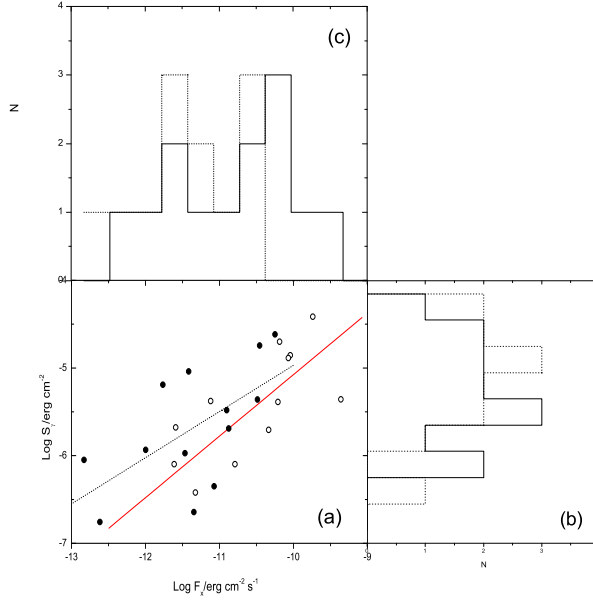


Fig. 1 Two-dimensional distributions of the gamma-ray fluences and the X-ray fluxes for the optically bright [open circles in panel (a) and solid lines in panel (b) and (c)] and the optically dark GRBs [solid circles in panel (a) and dotted lines in panels (b) and (c)]. The solid and dotted lines in the panel (a) are the best fit results for the bright and dark GRBs, respectively.

4 RATIO OF EARLY X-RAY AFTERGLOW FLUX TO AVERAGE GAMMA-RAY FLUX

GRBs are from cosmological distance. The observables must be affected by the cosmological effect. Since most of the bursts in our sample have no redshift measurements, we could not make the cosmological corrections. The hardness ratio between two observed energy bands is independent of the cosmological effect. We thus study the hardness ratios of the two kinds of GRBs. The hardness ratio is calculated by the average gamma-ray flux to the X-ray flux, which is $R_{\gamma,X} = \overline{F_{\gamma}}/F_X$, where $\overline{F_{\gamma}}$ is the average gamma-ray flux over the duration (T_{90}) in 15-350 keV band. The distributions of $R_{\gamma,X}$ for the two kinds of GRBs are shown in Figure 2. The two-dimensional distributions in the panel (a) of Figure 2 show that two kinds of GRBs are mixed together without any classification signatures. The panel (b) of Figure 2 shows that the $R_{\gamma,X}$ distributions for the two kinds of GRBs are similar, with the $R_{\gamma,X}$ of the D-GRBs being slightly larger than that of the B-GRBs. We perform a K-S test to examine whether or not the two distributions are from the same parent. The significant level for the null hypothesis that two data sets are from the same distribution is $P_{KS} = 0.098$. The null hypothesis is marginally accepted.

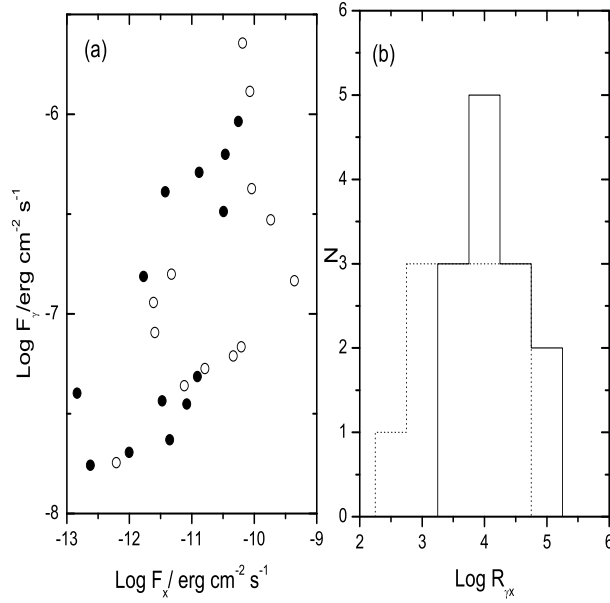


Fig. 2 Two-dimensional distributions of the average gamma-ray fluxes and the X-ray fluxes for the optically bright [open circles in panel (a) and solid lines in panel (b)] and the optically dark GRBs [solid circles in panel (a) and dotted lines in panels (b)].

5 BOOTSTRAP TEST

De Pasquale et al. (2003) found that the extrapolated X-ray afterglow fluxes at 11 hours since GRB trigger of the D-GRBs tend to be weaker than that of the B-GRBs with a factor ~ 6 . The means of the F_X for the D-GRBs and B-GRBs in our sample are $\overline{\log F_X} = -11.39 \pm 0.82$ and $\overline{\log F_X} = -10.66 \pm 0.85$, respectively. The $\overline{\log F_X}$ of the D-GRBs is slightly smaller than that of B-GRBs with a factor of ~ 5 . However, this difference is within the large error scopes of the means, and it is not in any statistical sense. The K-S test indicates that the F_X distributions for both D-GRBs and B-GRBs are drawn from the same parent. We use a bootstrap method to examine if the slight difference between them is due to the statistical fluctuation. We bootstrap 10^3 pair samples of D-GRBs and B-GRBs, and then calculate the P_{KS} for each pair sample. The distribution of the P_{KS} is shown in Figure 3, indicating the hypothesis that the pair samples are drawn from the same parent is accepted at a significance level of $\sim 3\sigma$. We also combine each pair samples as an assembled sample and then apply KMM algorithm (Ashman et al. 1994) to examine if the assembled sample can be classified as two unique groups. It is found that the null hypothesis, which suggests that the assembled sample is classified into two unique groups, is ruled out at a significance level of $\sim 3\sigma$.

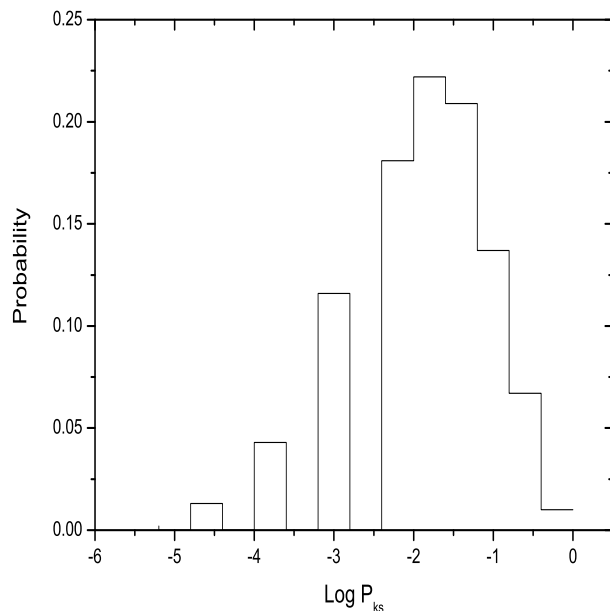


Fig. 3 The P_{KS} distribution for 10^3 pair bootstrap samples.

6 CONCLUSIONS AND DISCUSSION

With a homogenous sample detected by Swift we have shown that the distributions of F_X , S_γ , and $R_{\gamma,X}$ for both the D-GRBs and B-GRBs are from the same parent. These results indicate that the progenitors of the two kinds of GRBs are the same population. Their total energy explosions are comparable. The suppression of the optical emissions from D-GRBs should be resulted from circumburst.

As suggested by Roming et al. (2005), the mechanisms to suppress the optical emissions from the D-GRBs might be diverse. This diversity may reflect the variety of the circumburst. The extinction effect is the most popular model to explain these D-GRBs. However, the dust in the host galaxy may be destroyed by early radiation from γ -ray burst and their afterglows (Waxman & Draine 2000; Fruchter et al. 2001). It is found that the optical extinctions are 10~100 times smaller than expected from X-ray absorption (Galama et al. 2001). We examine the X-ray absorptions in our GRB sample. We do not find systematically difference of excess nH values for the D-GRBs and B-GRBs. Extinction effect alone is hard to explain the nature of the darkness of these GRBs. The darkness should be responsible for more physical mechanisms. Most recently, Liang & Zhang (2005) found an intriguing results that within optically bright GRBs there exists two unique classes of GRBs with late optical afterglows. In their sample a minority of GRBs have a luminosity dimmer than the typical ones with a factor ~ 30 . If this is true the nature of the dim group may cast a light on the D-GRBs.

Here we give a possible explanation that the optical dark bursts may be caused by the synchrotron self-absorption (SSA) (Granot, Piran 1999). If the SSA frequency is a little greater than the observed optical frequency, which may be caused by the larger circum-density (Sari 1998) or more loading baryons, the optical afterglow will be darker than that in the case that the SSA can be neglected.

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Table 1 The observational data of our GRB sample

GRB	S_γ $10^{-6} \text{ ergs cm}^{-2}$	T_{90} sec	$\text{Log}(F_X)$ $\text{ergs cm}^{-2}\text{sec}^{-1}$	Ref ^a
Dark GRBs				
GRB050124	2.10	4.1	-10.88	1;1;1
GRB050126	1.10	30	-11.47	3;2;-
GRB050128	4.50	13.8	-10.49	4;3;5
GRB050215b	0.23	10	-11.35	7;;7
GRB050219a	9.40	23	-11.42	7;6;7
GRB050219b	24.90	27	-10.26	7;8;7
GRB050223	0.92	23	-12.84	7;9;7
GRB050326	18.60	29.5	-10.46	7;10;7
GRB050410	6.63	43	-11.77	7;11;7
GRB050421	0.18	10.3	-12.62	7;12;7
GRB050422	1.20	59.2	-12.00	7;16;7
GRB050509a	0.46	13	-11.08	7;17;7
Bright GRBs				
GRB041223	38.50	130	-9.74	23;24;
GRB050315	4.20	96	-11.12	3;3;7
GRB050318	1.97	32	-10.34	7;3;7
GRB050319	0.80	15	-10.79	7;3;7
GRB050401	14.00	33	-10.04	3;25;14
GRB050406	0.09	5	-12.21	7;26;7
GRB050412	2.10	26	-11.59	7;27;7
GRB050416a	0.38	2.4	-11.33	7;3;7
GRB050502b	0.80	7	-11.61	7;28;7
GRB050505	4.10	60	-10.21	3;3;7
GRB050525a	20.00	8.8	-10.19	3;3;7
GRB050603	13.00	10	-10.07	7;29;7
GRB050607	0.89	26.5	-11.51	13;3;15

Notes:^a In order of: S_γ ; T_{90} ; F_X **References:**

(1) Cummings et al. 2005a; (2) Sato et al. 2005; (3) Nousek et al. 2005 (4) Cumming et al. 2005b; (5) Antonelli et al. 2005; (6) Hullinger et al. 2005a; (7) Roming et al. 2005; (8) Cumming et al. 2005c; (9) Mitani et al. 2005; (10) Cumming et al. 2005d; (11) Fenimore et al. 2005a; (12) Sakamoto et al. 2005a; (13) Retter et al. 2005; (14) De pasquale et al. 2005; (15) Burrows et al. 2005; (16) Suzuki et al. 2005; (17) Hurkett et al. 2005; (23)

Markwardt et al. 2005; (24) Tueller et al. 2005; (25) Sakamoto et al. 2005b; (26) Krimm et al. 2005; (27) Fox et al. 2005; (28) Falcone et al. 2005; (29) Fenimore et al. 2005